Progress on the Maskless Micro-Ion Beam Reduction Lithography System*

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A maskless projection lithography approach called Maskless Micro-ion-beam Reduction Lithography (MMRL) has been developed at Lawrence Berkeley National Lab (fig. 1). After the proof-of-concept machine was built, tremendous work has been done to decrease the geometrical and chromatic aberrations by employing a limiting aperture on the beam cross-over plane, which improved the resolution from about 1 μm to better than 150 nm.[1] Aberrations theory predicts that the resolution in the center of the exposure field will always get better and better by just decreasing the limiting aperture diameter. But we didn't observe this trend when the limiting aperture diameter is below 100 μm. There must be some other factors that affect the performance of the system, such as environmental fluctuation, high voltage power supply instability.

The PMMA resist exposure result at different dose level is shown in Fig 2. At very high dose, large elliptical contact holes were obtained. Decreasing the dose, two small deep holes appeared inside the large crater. Further decreasing the dose, two well-apart contact holes were obtained with less than 60 nm diameter. This result can be explained if the electromagnetic interference (EMI) was considered. A VLF ac magnetic field with 0.2 mGauss rms amplitude perpendicular to the column axis had been measured inside the system chamber. Theoretical investigation was performed. First, the helium ion beam energy distribution along the column axis was obtained from a finite element calculation. Then utilizing the ion beam energy distribution and the 0.2 mGauss ac magnetic field, 250 nm ion beam swing on the wafer plane was obtained in calculation. The swings from two 60 Hz sinusoidal ac magnetic fields with different phases, amplitudes and directions (but both lie in the plane normal to the column axis) can create an elliptical periphery. The convolution of the sinusoidal swing with a gaussian-shape beam can generate a distorted beam with double peaks (fig. 3). Current MMRL system can only give about one-third attenuation to the outside VLF ac magnetic field. A new EMI shielding is going to be installed to give another 90 percent attenuation to the outside ac magnetic field and almost 99 percent attenuation to the ac electric field. The shielding to the electrical parts around the test-stand area will also be considered. The individual hole in the exposure result shows the resolution might be better than 60 nm. The further experimental result for the new EMI shielding and the detailed calculation results will be presented.

In order to further improve the resolution, the instability of the high voltage power supplies should be evaluated. The pulsed ion current collected by the limiting aperture is usually much higher than that landed on the wafer, which gives a high load change to the high voltage power supply of the limiting aperture. The dynamic response of the ultra-low ripple high voltage power supply can be several hundred ms. During this period of time the voltage on the limiting aperture is not stable, which will defocus the ion beam. This effect will be severe at high-throughput condition without upgrading the current MMRL high voltage power supplies.

[1] Ximan Jiang, Qing Ji, Lili Ji, Audrey Chang, and Ka-Ngo Leung, J. Vac. Sci. Technol. B21, 2724 (2003).

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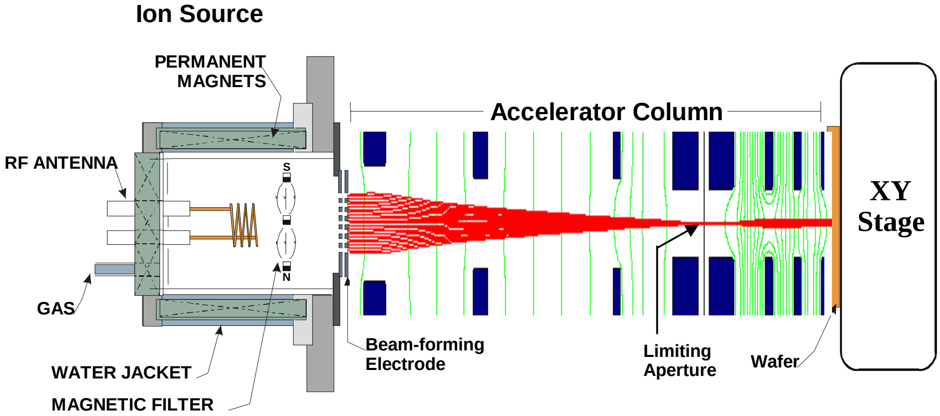

Figure 1: The MMRL is an ion beam projection lithography system without illumination column. It can also work in maskless mode by using many switchable apertures on beam-forming electrode to generate different patterns on the resist.

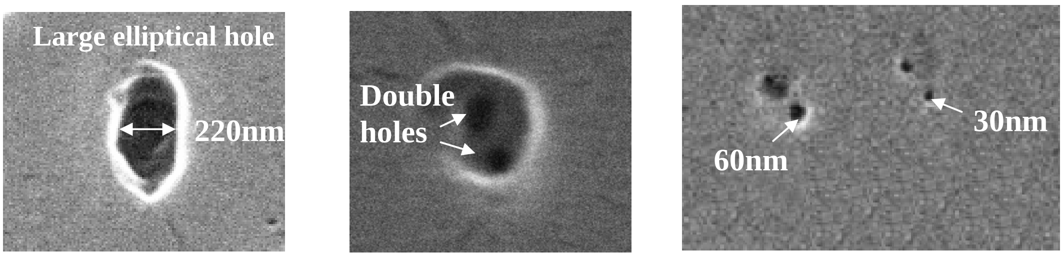

Figure 2: The doses of the exposures decrease from left to right. The swing direction might change because the ac field direction might also change with time.

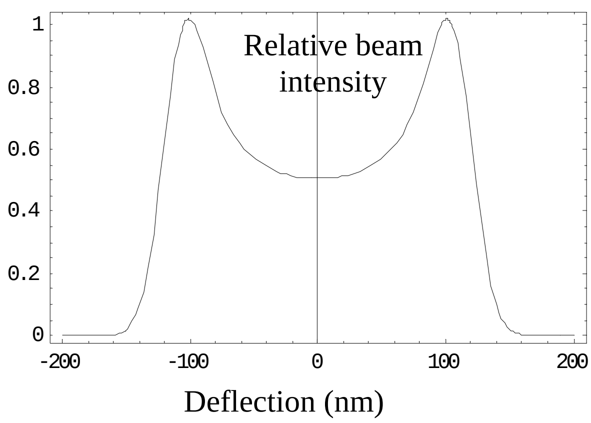

Figure 3: Cross-sectional view of the distorted beam